Monsoon Disturbances Over Southeast and East Asia and the Adjacent Seas

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LONG TERM GOALS

To study weather disturbances over the Southeast and East Asian monsoon region and its adjacent seas (e.g., tropical western Pacific, Indian Ocean, South China Sea, Yellow Sea, etc.) using Navy research and operational analysis and forecast models. The primary goal is to advance the understanding of the weather-producing systems in the region, in order to improve forecast capabilities. In the process we will assess the skill and characteristics of the models and the suitability of different physical parameterization schemes in representing and forecasting these disturbances, and find clues that may be useful for model improvement efforts.

OBJECTIVES

The objectives are: (1) to study the structure and the dynamic and thermodynamic properties of the disturbances in the vicinity of the Southeast and East Asian monsoon region that stretches from Indian Ocean to the tropical western Pacific, including the South China Sea and Yellow Sea, which are of particular interest to naval operations; and (2) to study the ability and sensitivity of Navy operational numerical models in analyzing and predicting these disturbances. The key questions to be answered are the development and evolution mechanisms of these disturbances and their interactions with the different stages of the large-scale monsoons in the atmosphere. For summer monsoon the focus is on the convective disturbances (“Mei-yu” in China, “Changma” in Korea and “Baiu” in Japan) that developed following the onset and reinforcement of the southwest monsoon in the South China Sea. For winter monsoon the focus is on the cold surge and weather disturbances in the vicinity of the South China Sea and the maritime continent. The current Navy operational model, COAMPS, has not been tested systematically in the tropical, monsoon environment. The importance of cumulus convection, the tropical dynamics, and the topographic effects in East and Southeast Asia and the surrounding seas provide a quite different challenge for the simulation and forecasting capability of COAMPS as compared to other parts of the world. Therefore, an important objective is to study the characteristics of the model's performance and sensitivity in the East Asian monsoon region, in order to improve the model forecast skill and to find the optimal application methodology for Navy operations.

APPROACH

Observational studies/Data analysis: Use archived gridded data from global NWP outputs and satellite data to determine the structure of mesoscale and synoptic disturbances in various local regions for the

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different seasons. Use composite and principal component approaches to perform statistical analysis of the data.

Numerical modeling: Perform sensitivity and simulation studies of the observed monsoon disturbances with Navy's regional research and operational models. Cold start with NOGAPS fields and continued integration using update cycles. Carry out sensitivity studies with respect to physical parameterizations, grid sizes, and data impacts. Verify model forecasts and analyze model results with results of observational study using diagnostic tools.

WORK COMPLETED

For the winter monsoon, a diagnostic study was carried out to study the interactions between the northeasterly cold surges and the Madden-Julian Oscillation in the vicinity of the South China Sea and western Pacific monsoon region.

For the summer monsoon, a preliminary forecast of the pre-onset case in the South China Sea during the South China Sea Monsoon Experiment (SCSMEX) was conducted using COAMPS, with NOGAPS data as boundary conditions.

RESULTS

1. Interaction of the northeasterly cold surges and the Madden-Julian Oscillation during the winter monsoon.

During northern winter monsoon, the Madden-Julian Oscillation (MJO) and northeasterly cold surges are active over the tropical eastern Indian Ocean and western Pacific. Taylor (1998) has shown that both motion systems are important in the development of tropical cyclones. We examined the interactions between the two motion systems during the 1979-1998 period using the NCEP Reanalysis 1000 hPa wind and OLR data. Based on the linear equatorial dynamics theory with anomalous heating (Gill 1980, Lau and Peng 1987), the MJO circulation and convection patterns can be represented by a combination of Rossby and Kelvin wave responses. During the MJO active phase, enhanced convection over the equatorial region of the South China Sea produces lower pressure and therefore a stronger pressure gradient that favors cold surge. However, the cyclonic flow associated with the Rossby mode response in the northern subtropics produces southwesterlies in the northern South China Sea and opposes the surge. The net results of these competing effects are analyzed by dividing the MJO into four phases (early active, late active, early inactive, late inactive) in the South China Sea, and the cold surge events into two stages: (day 1-6 and day 7-12, with day 0 defined as the day of minimum northerly in northern South China Sea).

During the early active phase (Fig. 1 – left part), the MJO convection helps intensify the cold surge by creating an area of lower pressure. Surges are longer in duration as a result of MJO convection persisting over the area. For the early inactive phase (Fig. 1 – right part), the lack of organized MJO convection hinders the surge. However, a few surges occur in this phase as a result of mid-latitude forcing. As the early inactive phase progresses out to day 7-12, the surges are no longer present. During surge day 1-6 of the late active phase (Fig. 2 – left part), the MJO convection helps to intensify the surge events. The Rossby mode pressure-wind pattern opposes the surge, but its effect is dominated by the convective effects of the MJO. As a result, this period contains the highest frequency of surges. Later into the period (day 7-12), the MJO convection moves out of the South China Sea so surges are hindered by the Rossby mode pressure-wind relationship. During the late inactive phase (Fig. 2 – right part), the Rossby mode pressure-wind pattern helps the surge for surge day 1-6. However, the surge is hindered by the lack of the MJO convection that tends to be associated with anomalously higher surface pressure in the equatorial South China Sea. The frequency of surges is therefore minimum in this situation. Later in the period (surge day 7-12), the MJO dry segment moves out of the area, the monsoon surges are helped by the pressure wind pattern and the frequency of surges increases.

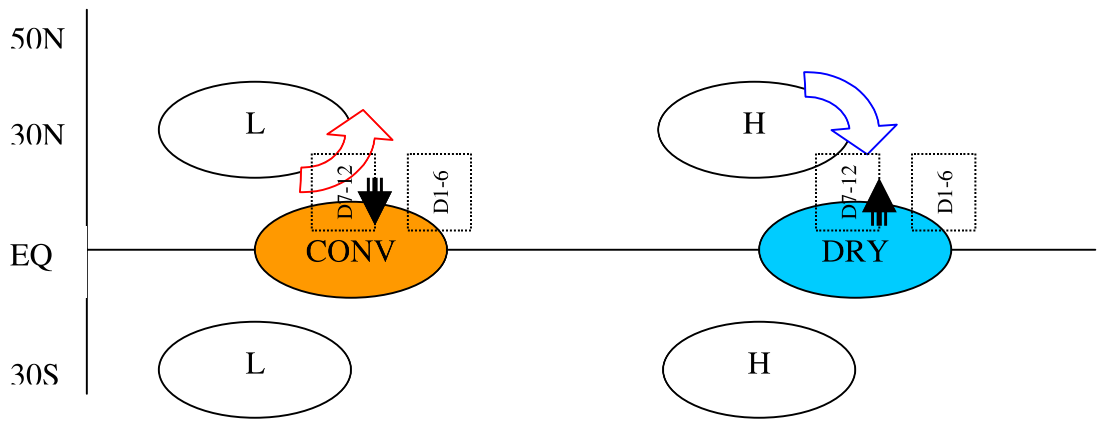

Fig. 1. Schematic structure relative to the eastward propagating MJO for early active (left) and early inactive (right) phases. The relative locations of the South China Sea during surge day 1-6 and surge day 7-12 are indicated by dashed rectangular boxes. Colored areas indicate convection (orange) and dry (blue) areas, which provide a tendency of anomalous meridional pressure gradient force (bold arrow heads) that may favor (towards convection area) or hamper (away from dry area) the northeasterly cold surges. The MJO Pressure-wind relationship is indicated by open arrows (red: poleward, blue: equatorward) circulating around pressure centers, which favors surges in the active phase and oppose the surges in the inactive phase.

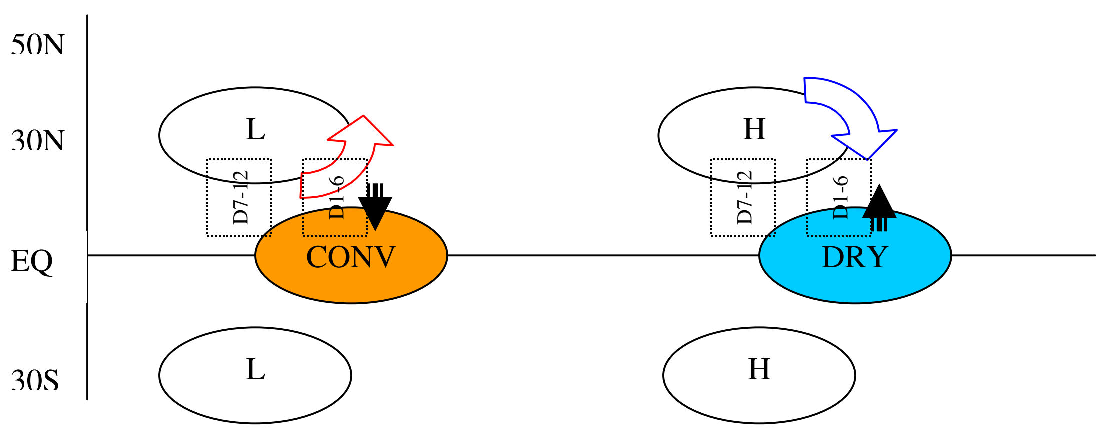

Fig. 2. As Fig. 1 except for late active (left) and inactive (right) phases.

2. Summer monsoon COAMPS forecasting experiments: A pre-onset southwesterly surge case during SCSMEX.

In FY 00 we completed all the preparation work and the transition from NORAPS to COAMPS as the research model. We conducted a preliminary COAMPS forecast for the May 13-15, 1998 pre-monsoon onset case. With the Kain-Frisch cumulus scheme the model accurately predicted the location of the subtropical frontal precipitation in the northern South China Sea and East China Sea, but shows a trend of increasing rainfall as the integration time continues from 24 h to 72 h. At 24 h the rainfall is under-forecasted, while at 72 h it is over-forecasted. The initial underforecast appears to be a result of the explicit cloud physics incorporated in the large-scale precipitation scheme that is used as a companion of the Kain-Frisch scheme. Indian Ocean the model produced large errors , with unrealistically large precipitation north of the equator and fictitious rainfall in the southern tropics. When the cumulus scheme is shifted to Kuo scheme, the bias of early (at 24 h) underforecast of rainfall disappears as a result of the simpler companion large scale precipitation scheme. The rainfall forecast at 72 also show less overforecast bias. However, the rainfall patterns are less organized.

There are excessively large latent heat fluxes over elevated land areas during day time. The problem is especially serious over the Tibetan plateau, where the surface latent heat fluxes in the afternoon exceeds those over the surrounding tropical ocean. Work is in progress to find a proper adjustment of the model's surface latent heat flux calculations over such land area.

IMPACT

During northern winter the MJO and cold surges are dominant factors influencing the development of severe weather systems, including tropical cyclones, in the South China Sea and tropical western Pacific. Understanding their interactions will help their proper simulation in the model and the efforts to improve forecast diagnosis, evaluation and application.

The preliminary COAMPS simulation of the pre-onset summer monsoon case during SCSMEX revealed significant errors in the East and Southeast Asian monsoon region, in particular the tendency of fictitious convection belt over the tropical oceans and unrealistically large latent heat fluxes over land. This lays the foundation for model sensitivity studies, in order to provide feedback to the modelers on the model performance and special characteristics for the monsoon area.

RELATED PROJECTS

Joint work with NSF Project on East Asian Monsoon at NPS. The NSF project conducted observational and theoretical studies of the Asian monsoon motions and complements the numerical modeling efforts of this project.

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